

# **Geometric and radiometric assessment of CBERS and Landsat products generated by INPE**

# CBERS-2B radiometric evaluation

Signal to noise ratio

MTF performance – effective resolution

Effective spectral bands

Relative and absolute calibration

# CBERS-2B cameras

## CCD

B1: 0.45 – 0.52  $\mu\text{m}$ ; B2: 0.52 – 0.59  $\mu\text{m}$ ; B3: 0.63 – 0.69  $\mu\text{m}$   
B4: 0.77 – 0.89  $\mu\text{m}$ ; B5: 0.51 – 0.73  $\mu\text{m}$   
Swath: 117Km; Resolution: 20m

## HRC

B6: 0.45 – 0.85  $\mu\text{m}$   
Swath: 27Km; Resolution: 2.36m

## WFI

B7: 0.63 – 0.69  $\mu\text{m}$ ; B8: 0.77 – 0.89  $\mu\text{m}$   
Swath: 890Km; Resolution: 258m



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# CCD signal to noise ratio

SNR (dB) Camera CCD CBERS-2B			
Band	Specification	Measured (lab)	Measured
	min	min	mean
B1	32	36.4	33.0
B2	31	40.1	34.0
B3	26	32.0	37.0
B4	29	29.3	31.0
B5	37	38.8	33.0

# HRC signal to noise ratio

SNR (dB) Camera HR CBERS-2B		
Band	Specification (min)	Measured (mean)
B6	26	31.6

# WFI signal to noise ratio

SNR (dB) CBERS-2B Camera WFI		
Band	Specification	Measured (mean)
	(min)	
B7	18	21
B8	24	24

# MTF performance

Bands	Bands ( $\mu\text{m}$ )	CBERS2B CCD EIFOV (across-track during integration)	CBERS2 CCD EIFOV
B1	0.45 — 0.52	45	61 36
B2	0.52 — 0.59	51	59 35
B3	0.63 — 0.69	33	58 43
B4	0.77 — 0.89	70	63 37
B5	0.51 — 0.73	40	60 48

# MTF performance

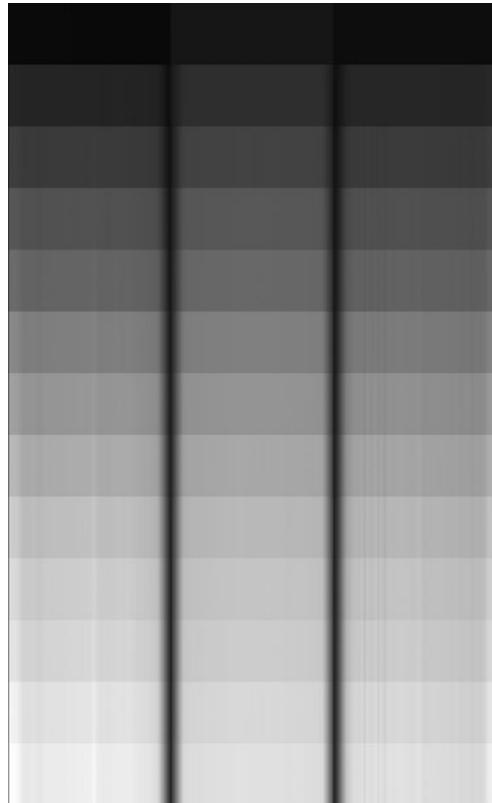
	Spectral Bands ( $\mu\text{m}$ )	MTF Across track, nadir (Nyquist frequency)
CCD	0.45 – 0.52	>0.28
	0.52 – 0.59	
	0.63 – 0.69	
	0.77 – 0.89	>0.20
	0.51 – 0.73	>0.28
HR	0.50 – 0.80	> 0.15
WFI	0.63 – 0.69	> 0.30
	0.77 – 0.89	



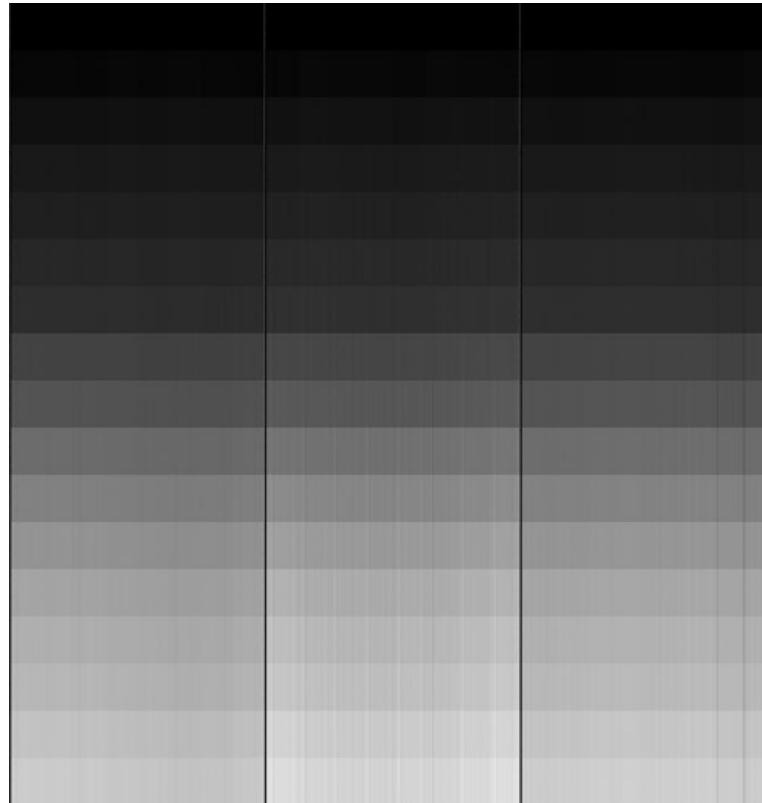
# CCD effective spectral bands

Band	Specification ( $\mu\text{m}$ )	Measurement ( $\mu\text{m}$ )
B1	0.45 — 0.52	0.465 — 0.530
B2	0.52 — 0.59	0.530 — 0.605
B3	0.63 — 0.69	0.635 — 0.705
B4	0.77 — 0.89	0.785 — 0.895
B5	0.51 — 0.73	0.535 — 0.725

# Relative calibration (laboratory)

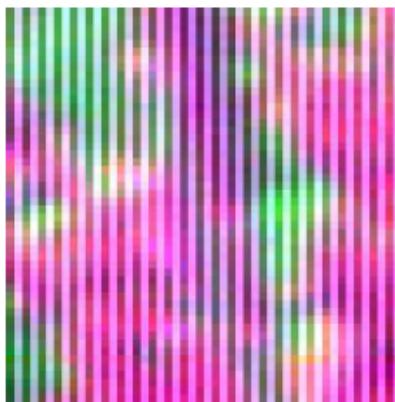


CCD – 12 illumination levels

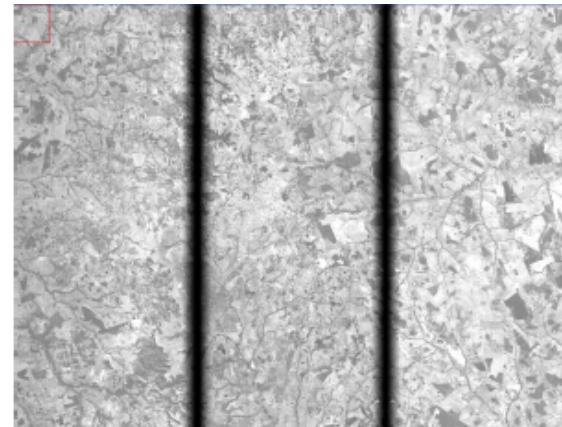


HRC – 16 illumination levels

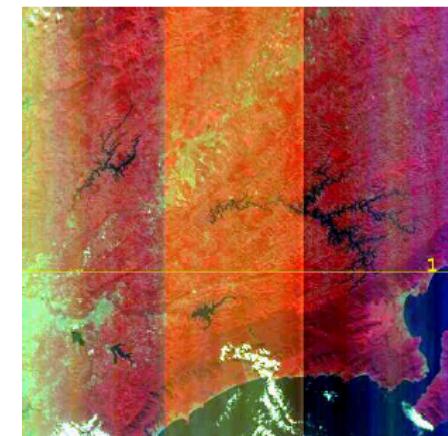
# CCD relative calibration corrections



Even/odd detectors



Arrays overlap



Arrays gain

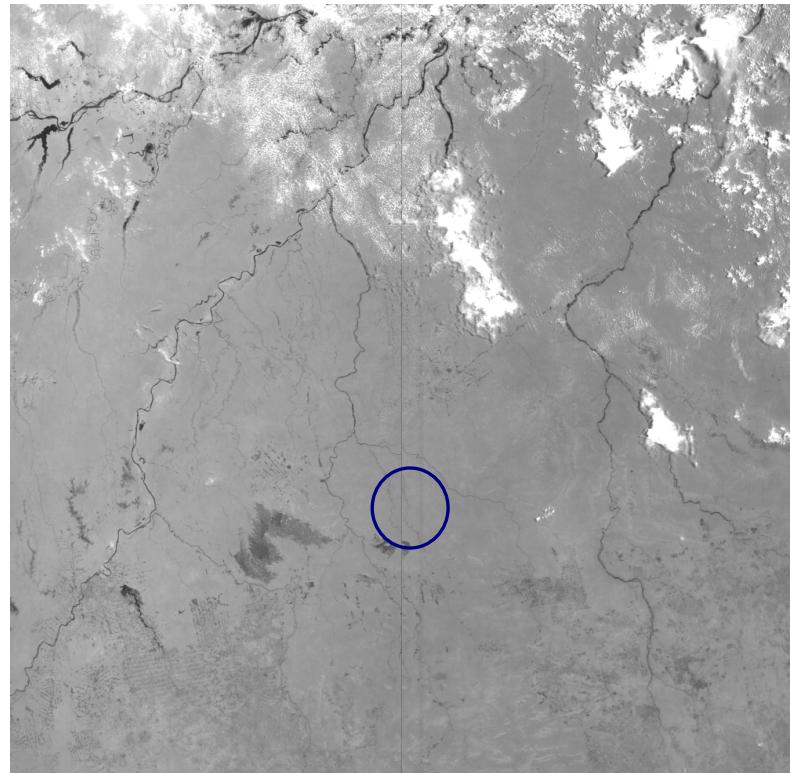


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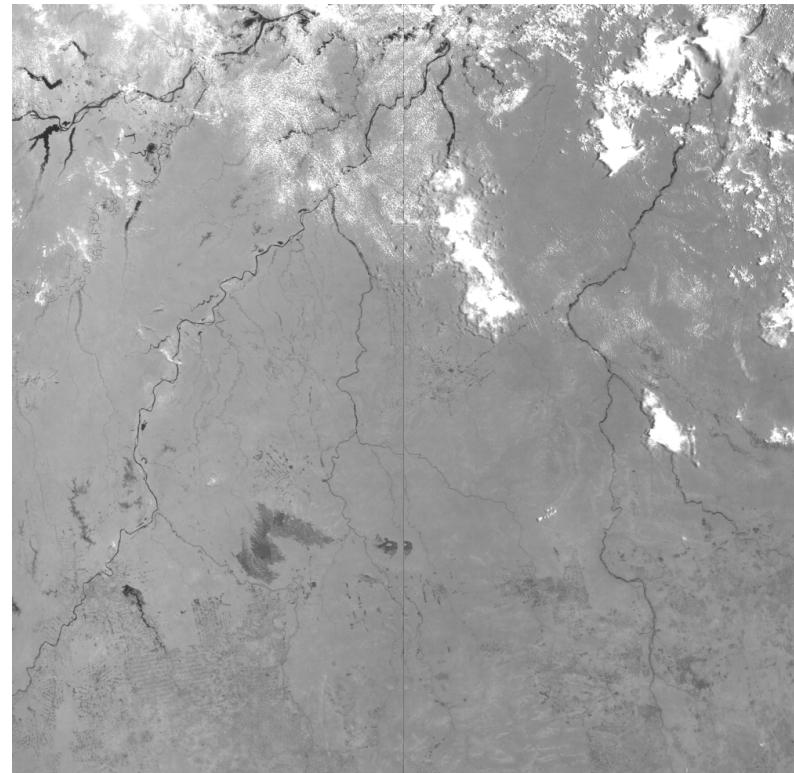
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# WFI relative calibration correction



Band 2 – before



Band 2 – after



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# CCD absolute calibration

Sphere level	Radiance B1	Radiance B2	Radiance B3	Radiance B4	Radiance B5
1	7,7897E-07	1,4029E-06	2,2186E-06	2,9146E-06	1,9229E-06
2	1,3629E-06	2,4664E-06	3,9203E-06	5,1818E-06	3,3931E-06
3	1,9398E-06	3,5430E-06	5,6900E-06	7,6108E-06	4,9122E-06
4	2,3821E-06	4,3867E-06	7,1053E-06	9,6096E-06	6,1222E-06
5	3,1503E-06	5,7458E-06	9,2153E-06	1,2319E-05	7,9586E-06
6	3,7621E-06	6,8594E-06	1,0997E-05	1,4674E-05	9,4978E-06
7	4,3125E-06	7,8791E-06	1,2646E-05	1,6905E-05	1,0919E-05
8	4,7997E-06	8,7877E-06	1,4148E-05	1,8983E-05	1,2207E-05
9	5,1212E-06	9,4001E-06	1,5176E-05	2,0449E-05	1,3086E-05
10	5,2863E-06	9,7445E-06	1,5821E-05	2,1488E-05	1,3624E-05
11	5,6124E-06	1,0368E-05	1,6861E-05	2,2968E-05	1,4514E-05
12	5,8266E-06	1,0793E-05	1,7621E-05	2,4108E-05	1,5153E-05



# CCD absolute calibration

<b>DN B1</b>	<b>DN B2</b>	<b>DN B3 (channel 1)</b>	<b>DN B3 (channel 2)</b>	<b>DN B4</b>	<b>DN B5</b>
7,2216	13,9768	22,5044	21,5410	36,5566	14,4474
12,9819	25,0359	40,9973	39,9283	66,0815	25,7021
18,6042	36,6945	60,0035	58,2990	97,6966	37,7373
23,1886	45,7590	75,3656	73,5063	122,9622	46,7995
30,5950	59,6615	97,7959	95,4196	157,1694	60,9508
36,8651	71,1365	117,0253	114,0012	186,5409	73,1810
42,6921	82,0510	134,7943	131,5717	213,7147	84,1012
47,7066	91,8982	150,6939	147,1328	219,2805	93,8939
51,2189	98,5908	162,1145	158,3522	218,7041	100,9613
53,2955	103,0795	169,3151	165,1416	217,7541	105,1296
56,8911	110,0054	180,0641	175,9726	216,2293	111,8926
59,4571	115,2994	188,3766	183,9564	215,5714	116,7368

# Landsat radiometric evaluation

TM

MS<sup>3</sup> uses USGS algorithms and CPF parameters

MS<sup>3</sup>: multi satellite station system by AMS Kepler

MS<sup>3</sup> L1 against LPGS L1R images

MS<sup>3</sup> product is generated in 8 bits

Additional processing converts DN to absolute radiance

30 sample pixels for each band

Radiance comparison for each sample pixel

Thermal band is not currently being calibrated

# Landsat radiometric evaluation

LANDSAT TM BAND	MAX RADIANCE DIFFERENCE	RADIANCE RANGE	% OVER RANGE
1	0.63	76.28	0.82
2	0.86	118.28	0.73
3	0.86	95.66	0.89
4	0.57	89.87	0.63
5	0.87	18.97	4.58
7	0.11	7.76	1.41

# Landsat radiometric evaluation

MS<sup>3</sup> L1 TM is as good as LPGS L1R TM

Radiance differences are less than 1 absolute value % over range are less than 5% in band 5, less than 2% in band 7, and less than 1% in bands 1, 2, and 3  
Any influence for typical users?

Memory effect

Correction still not implemented in MS<sup>3</sup>  
USGS provided uncorrected data for this evaluation

# Landsat radiometric evaluation

## MSS

### Statistical relative calibration

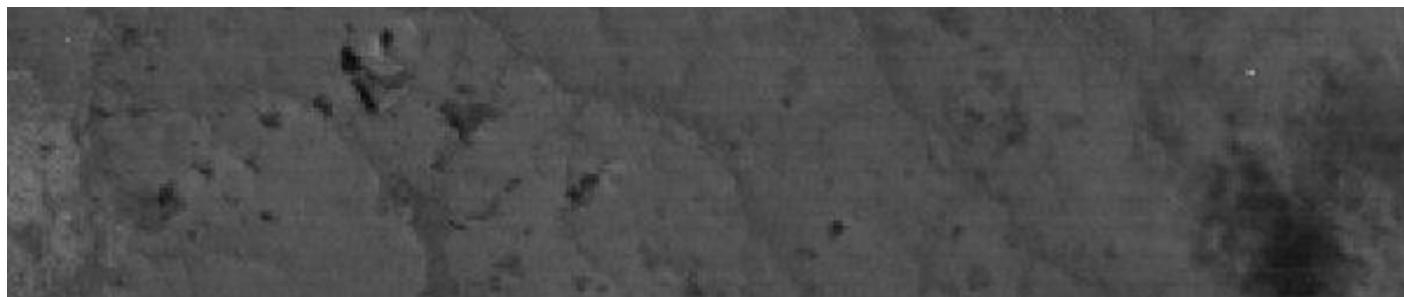
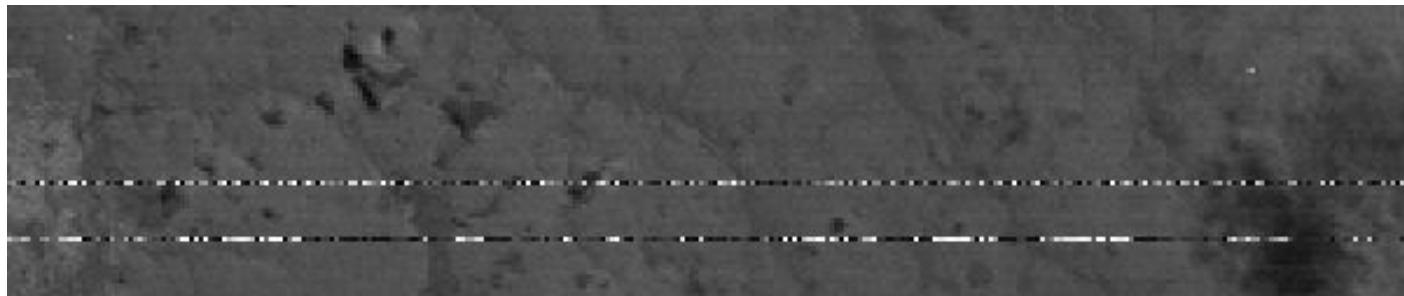
Detectors gains and offsets are computed in such a way that the average and standard deviation of each detector over the whole scene are the same

### Additional processing to remove bit slips

Detection and interpolation

# Landsat radiometric evaluation

## MSS bit slip correction



# CBERS-2B geometric evaluation

System-corrected WFI, CCD, HRC image data

Satellite drift

Geographic position of scene center

Band to band registration accuracy

Internal accuracy

Positioning accuracy

# Landsat geometric evaluation

System-corrected MSS, TM, ETM image data

Internal accuracy

Positioning accuracy

Geometric comparison between INPE and  
USGS system-corrected TM/ETM data

# Internal accuracy

Relative position of pixels with respect to a map projection system

- Landsat TM and ETM cameras have established the standards for moderate resolution

- Accurate attitude data

A good internal accuracy allows users to easily integrate images, maps, and other geographic data sources

# Internal accuracy

Control points for WFI, CCD, MSS, TM, ETM

Ortho-rectified moderate resolution images (L7, CB2)

Control points for HRC

Ortho-rectified high resolution images (QB, Prism) and GPS

Geometric transformations

Similarity and orthogonal transformations are used in the assessment

Affine transformation is used only to investigate image registration potential



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# Positioning accuracy

Global displacement of the image with respect to the earth surface

Landsat-5/7 satellites have established the standards

Accurate boresight, attitude, and ephemeris data

The positioning accuracy defines how far an image is from its true position

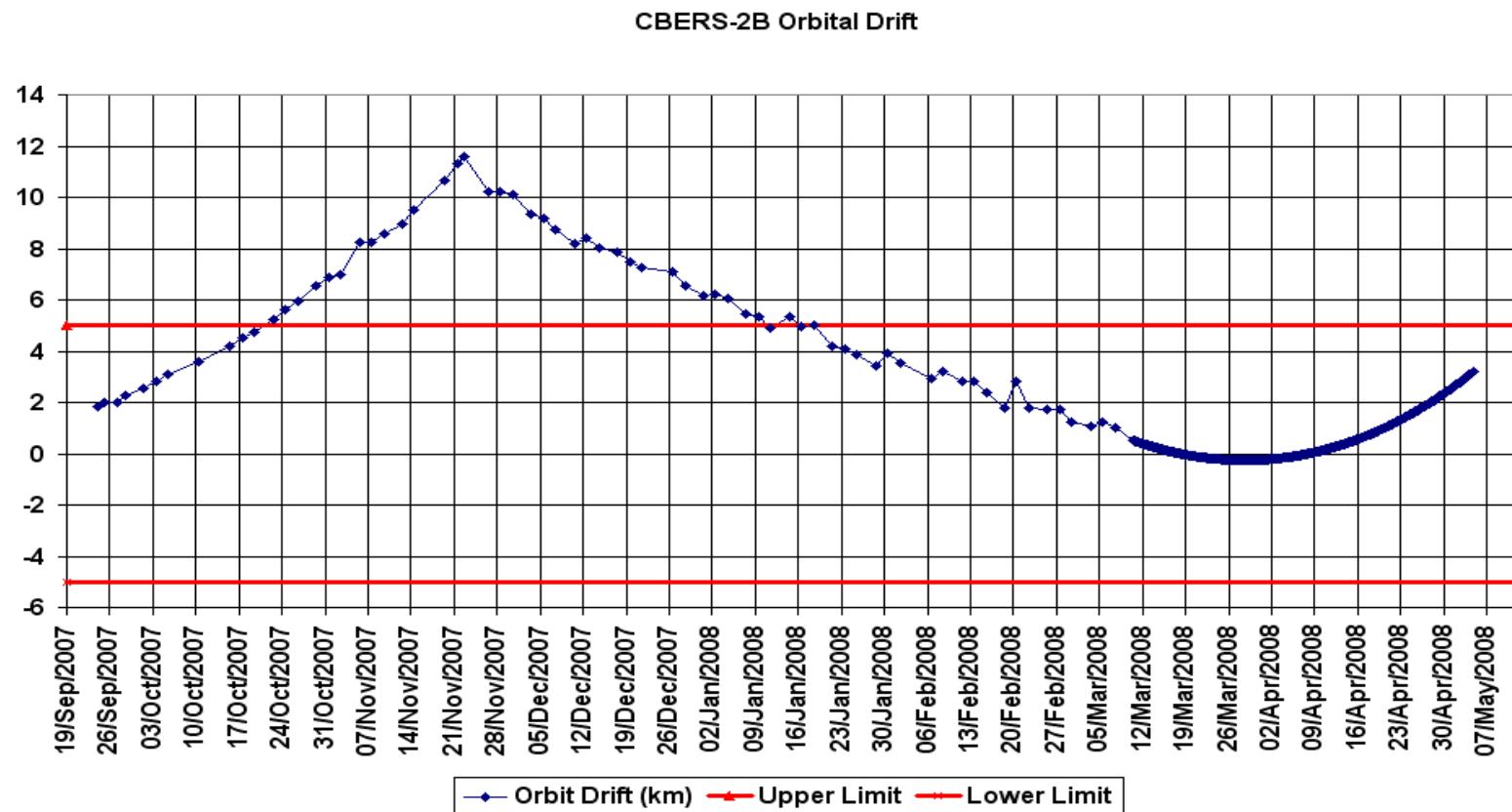
# Positioning accuracy

Difference between map projection coordinates  
computed in the geometric correction and  
actual map projection coordinates

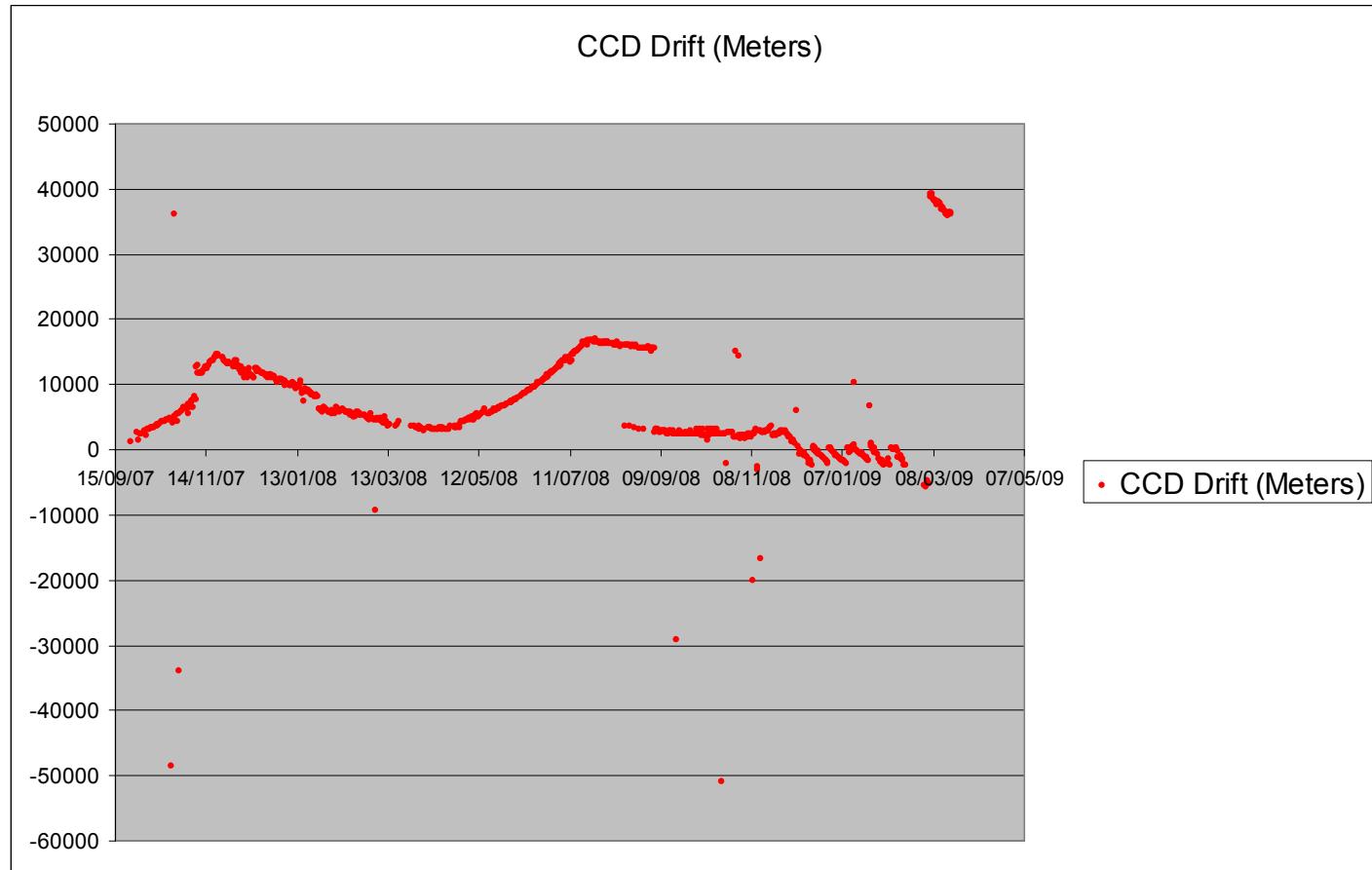
Direct comparison between control points coordinates

MS<sup>3</sup> processing system produces a report

# CBERS-2B satellite drift



# CBERS-2B satellite drift



# CBERS-2B satellite drift



CCD 159/121 – November 11, 2008



CCD 159/121 – March 12, 2009



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# CCD band to band registration

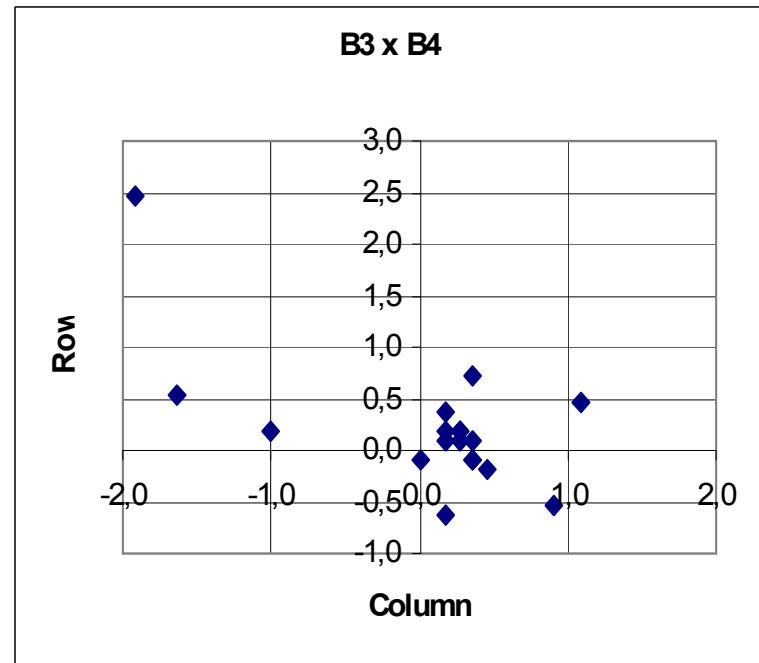
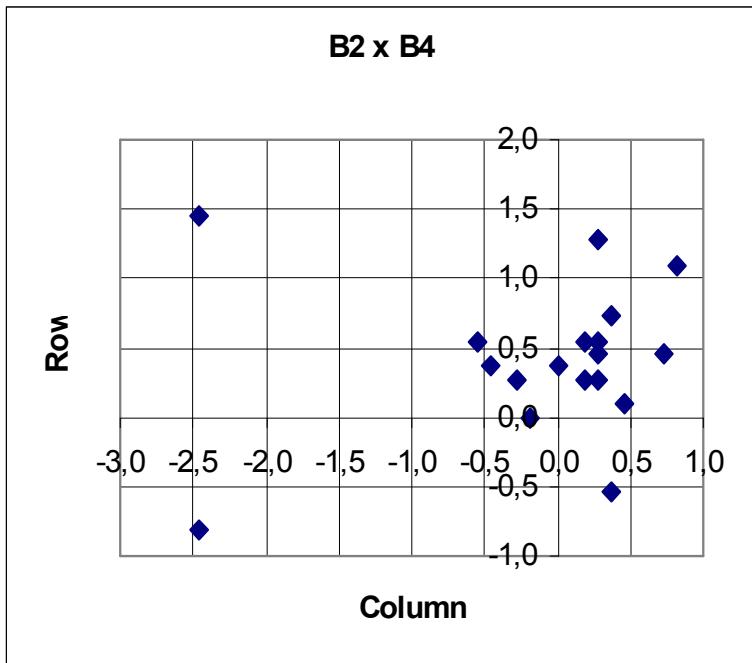
Reference and search windows are sub-images resampled up to 1/11 of the original pixel size

Overlay all possible positions to determine similarity on selected control points

Matching position at each control point is determined by the maximum similarity value

Spatial distance between any reference window and the corresponding matching position defines the band-to-band mismatch

# CCD band to band registration



# CCD band to band registration

Fixed Band:CBERS\_2B\_CCD2XS\_20090214\_159\_131\_L2\_BAND1#0

Shifted Band:CBERS\_2B\_CCD1XS\_20090214\_159\_131\_L2\_BAND2#0

Best Correlation coefficient:0.82

Delta x:0

Delta y:-0.25

Fixed Band:CBERS\_2B\_CCD2XS\_20090214\_159\_131\_L2\_BAND1#0

Shifted Band:CBERS\_2B\_CCD1XS\_20090214\_159\_131\_L2\_BAND3#0

Best Correlation coefficient:0.81

Delta x:0

Delta y:-0.25

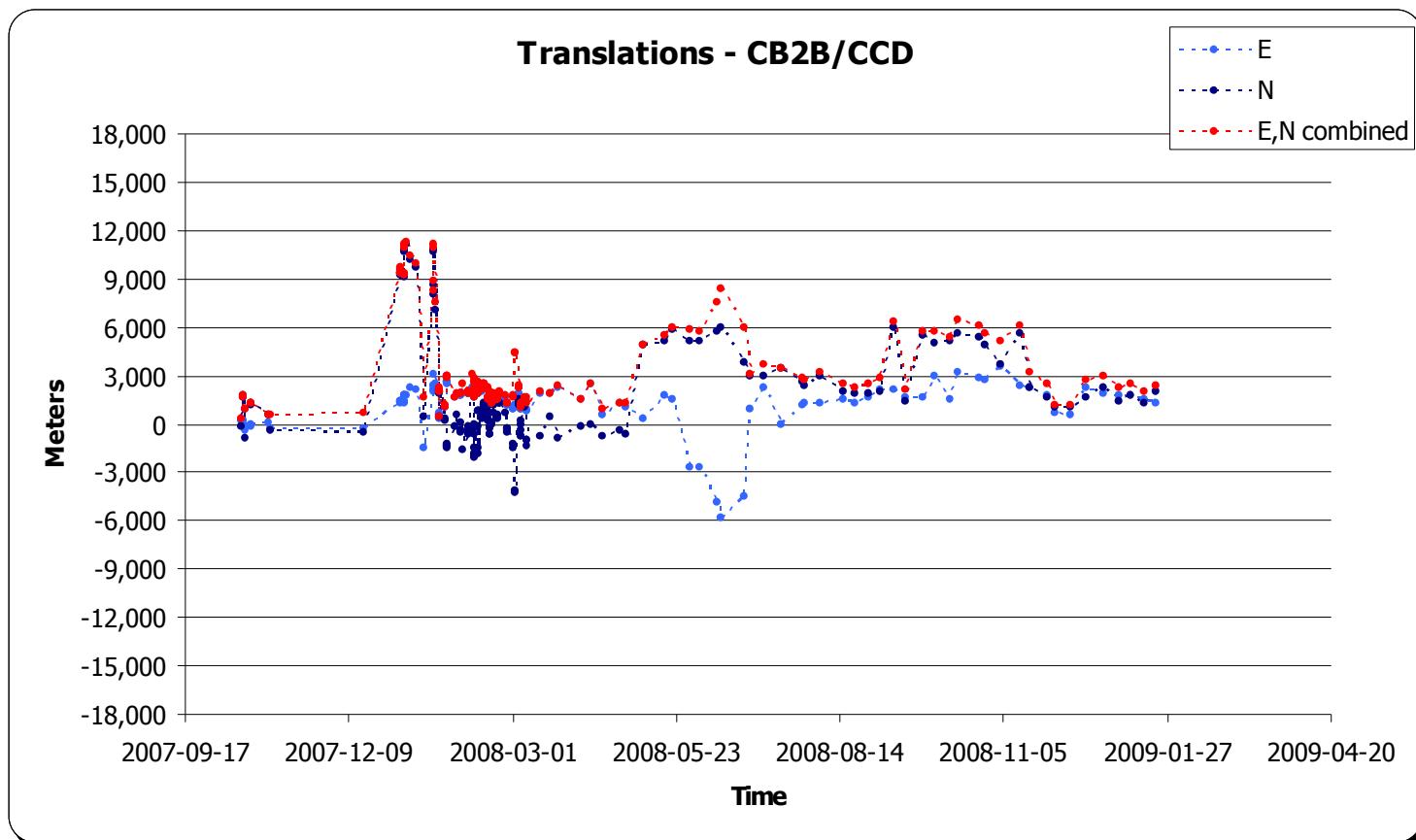
# CBERS-2B accuracy (orthogonal)

CAMERA	RMSE	SKEW	SIMILARIT Y	ANISOMORPHIS M	LENGTH
WFI	650m	0.15°	1.00	1.00	1.00
CCD	60m	0.15°	0.99	1.01	1.00
HRC	35m	0.15°	1.00	0.99	1.00

# CBERS-2B accuracy (affine)

CAMERA	RMSE	SKEW	SIMILARIT Y	ANISOMORPHIS M	LENGTH
WFI	293m	0.00°	1.00	1.00	1.00
CCD	20m	0.00°	1.00	1.00	1.00
HRC	24m	0.10°	1.00	0.99	1.00

# CBERS-2B positioning accuracy



# CBERS-2B geometric quality

CBERS-2B positioning accuracy lies within  
1,500m (easting) and 1,500m (northing)

GPS for ephemeris and AOCS for attitude data

WFI internal accuracy is around 2.5 pixels

CCD internal accuracy is around 3 pixels

Residual skew is caused by inaccurate attitude (yaw)

HRC internal accuracy is around 15 pixels

HRC behavior is not compliant with its TDI-CCD design

Focal distance has been frequently adjusted 

# Landsat geometric evaluation

## MSS

Boresight angles are considered as zero

USGS has just informed the correct boresight angles

Attitude angles are considered as zero

MS<sup>3</sup> supports ICT files, but they are not being used

Ephemeris are propagated from TLEs (Celestrak)

MS<sup>3</sup> supports BFET files, but they are not being used

Mirror profile assumed linear for Landsat 1/2/3

# Landsat geometric evaluation

## TM/ETM

MS<sup>3</sup> uses USGS algorithms and CPF parameters

Except for attitude processing, MS<sup>3</sup> uses quaternions

MS<sup>3</sup> supports

SAM and Bumper modes for TM

SLC-ON only for ETM

Ephemeris are propagated from TLEs (Celestrak)

Definitive Ephemeris coming soon



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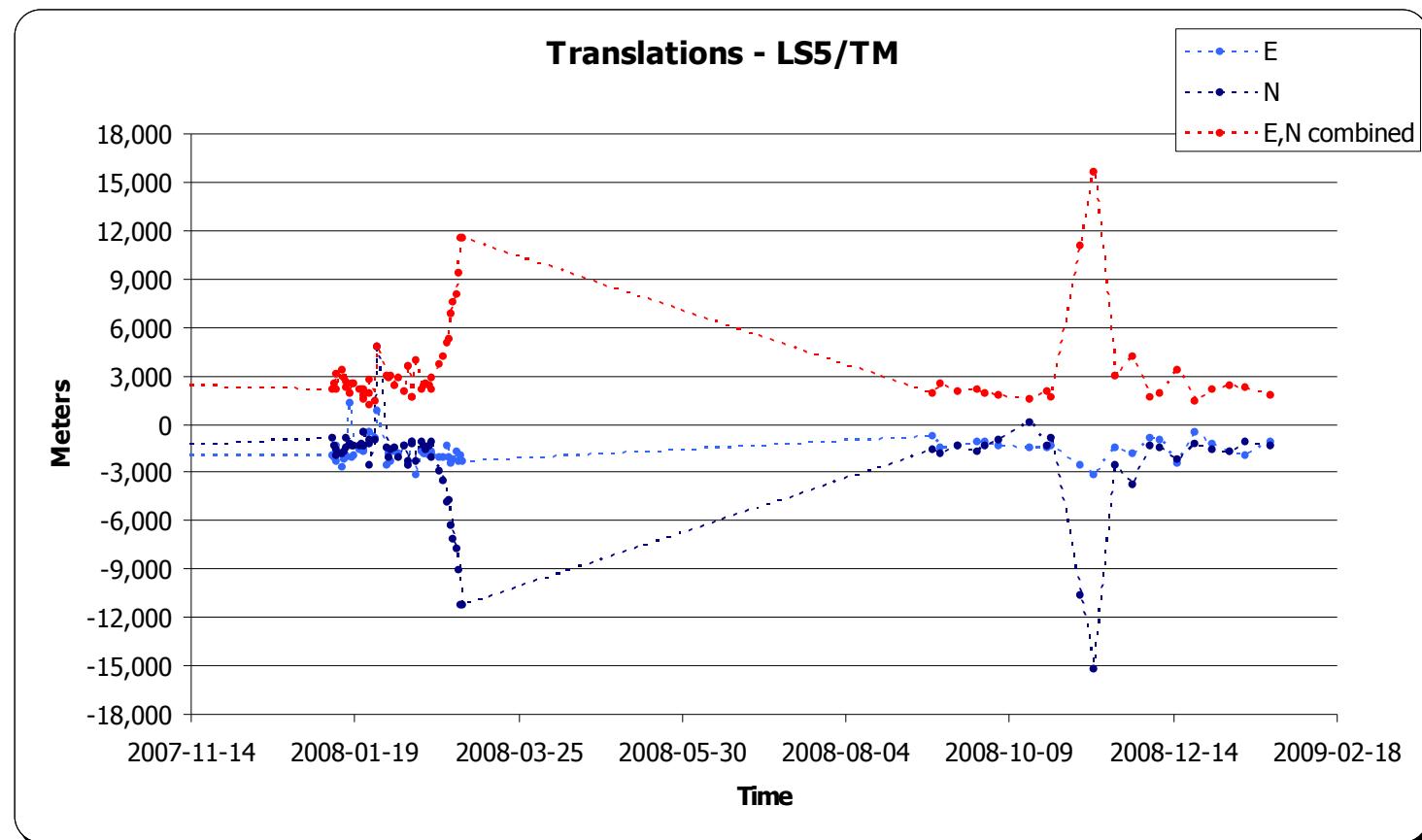
# Landsat accuracy (orthogonal)

CAMERA	RMSE	SKEW	SIMILARIT Y	ANISOMORPHIS M	LENGTH
MSS	711m	0.5°	0.99	1.00	1.00
TM	115m	0.05°	1.00	1.00	1.00
ETM	60m	0.05°	1.00	1.00	1.00

# Landsat accuracy (affine)

CAMERA	RMSE	SKEW	SIMILARIT Y	ANISOMORPHIS M	LENGTH
MSS	95m	0.06°	0.99	1.00	1.00
TM	30m	0.0°	1.00	1.00	1.00
ETM	30m	0.0°	1.00	1.00	1.00

# Landsat-5 positioning accuracy



# Landsat geometric quality

Landsat-5 positioning accuracy lies within  
1,600m (easting) and 1,400m (northing)

TLE for ephemeris and AOCS for attitude data

MSS internal accuracy is around 9 pixels

TM internal accuracy is around 3.5 pixels

ETM internal accuracy is around 2 pixels

# Comparison INPE – USGS

	LS5 SAM (telemetry)		LS5 Bumper (definitive)		LS7 (SLC on) (definitive)	
	MS <sup>3</sup>	NLAPS	MS <sup>3</sup>	LPGS	MS <sup>3</sup>	LPGS
E_translation (m)	183	305	1005	858	178	86
N_translation (m)	13	-10	745	737	-12	-77
RMSE (m)	55	23	63	50	46	46
CE90 (m)	119	50	136	105	99	99

# Comparison INPE – USGS

MS<sup>3</sup> TM/ETM L2 is as good as NLAPS/LPGS  
L1G

Internal accuracies are similar given the typical accuracy of measuring control points

Positioning accuracies are also comparable

## Geometric and radiometric assessment of CBERS and Landsat products generated by INPE

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**Thanks!**